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Phase separation in oxygen-deficient $TmBa_2Cu_3O_{6+x}$ superconductors

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Experiments on ^{169}Tm "enhanced NMR" support the idea that the superconductivity in oxygen deficient 1-2-3 compounds is provided by a percolative network of S-I-S nano-sandwiches.

1. INTRODUCTION

There are indications that at room temperatures non-stoichiometric $RBa_2Cu_3O_{6+x}$ compounds usually exist in a form of stable or metastable coherent mixture of microdomains of different phases[1]. As was seen from Gd impurity EPR spectra in YBCO[2], five combinations of "filled" and "empty" nearest neighbor CuO chain fragments form five types of RE centers K_i (i=0,1,2,3,4 denote numbers of "filled" chains, i=0,2,4 corresponding to T, OII and OI structures, respectively) in relative amounts well consistent with a model of 2D-ordering of chains in CuO basal planes. Being located in between CuO_2 planes RE ions seem to be excellent probes for investigations of basic properties of 1-2-3 systems. However, as a result of a difference in ionic radii the impurity RE ions substituted for Y always introduce distortions in the host crystal lattice giving rise to local effects in EPR spectra and spin-lattice relaxation of impurity paramagnetic centers[3]. In order to avoid such local effects one should use magnetically-concentrated RE1-2-3 cuprates. As the $ErBa_2Cu_3O_{6+x}$ compounds appeared to be very convenient for investigations of the phase separation phenomena using inelastic neutron scattering[4], the $TmBa_2Cu_3O_{6+x}$ compounds suit perfectly for studies of basic properties of 1-2-3 systems using the thulium "enhanced NMR"[5]. The ^{169}Tm NMR (spin I=1/2, 100% abundance), "enhanced" by a hyperfine interaction of the nuclei with 4f-electorns, is very sensitive to the structure of the crystal lattice[6]. The spectra are described by the Hamiltonian $H = -\hbar \Sigma \gamma_i H_i I_i$, whose parameters $|\gamma_b/2\pi|$ and $|\gamma_c/2\pi|$ at T<4.2K have the following values: 6.8(1) and 2.20(5) kHz/Oe in OI phase, 6.1(1) and 2.56(5) kHz/Oe in OII phase, and 5.3(1) and 3.05(5) kHz/Oe in T phase. A particular feature of these spectra is that the parameter $|\gamma_a/2\pi|$ remains at the value 5.3(1) kHz/Oe in all three main phases.

2. EXPERIMENTAL

The TmBCO samples were prepared by a conventional solid-state reaction method. The Tm NMR was performed at temperatures below 4.2 K by using a home-built pulsed spectrometer at frequencies of ~50 MHz. The diamagnetic susceptibility was measured with an ac 1 kHz-bridge (H_1=1 Oe). The temperatures down to 0.04 K were obtained by using the ^3He-^4He dilution refrigerator.

3. RESULTS AND DISCUSSION

The principal features of the Tm NMR in the samples aged at room temperature for more than 1 year are as follows[7,8]. The NMR spectra confirm the conclusions[2] concerning five types of RE^{3+} centers (K_0-K_4). The Tm nuclear spin-lattice relaxation (NSLR) obeys the so-called "Förster's law" $1-M_t/M_\infty=\exp(-(t/T_1)^{1/2})$ known to be valid for NSLR via paramagnetic impurities in the absence of a nuclear spin diffusion. Overall, the Tm NMR data in a combination with results of other investigations of YBCO compounds support the idea[4] that the superconductivity of oxygen-deficient 1-2-3 compounds is provided by a percolative network of mesoscopic platelike OI and OII domains. The superconductivity seems to be provided only by "sandwiches" consisting of identical (OI-OI or OII-OII) planes that are symmetrical with respect to the RE planes. The Tm NSLR data taken at

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